

## NOTES ON THE *MINDARUS* SPP. (HOMOPTERA: APHIDIDAE) OF NORTH AMERICA WITH DESCRIPTIONS OF TWO NEW SPECIES

DAVID VOEGTLIN

Center for Biodiversity, Illinois Natural History Survey, Champaign, Illinois 61820-6970.

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*Abstract.*—A background of the biology and taxonomy of *Mindarus* spp. in North America is presented. A previously unused character, wax gland plates on apterous adult female morphs, has been found to be relatively conservative and useful for discriminating between species. An extensive study of specimens from western North America and Europe suggests that *M. abietinus* Koch, a European aphid to which most specimens have been assigned, may not be present in the western Nearctic. Two species, *Mindarus kinseyi*, n. sp. living on *Abies concolor* and *M. remaudierei*, n. sp. living on *Abies religiosa*, are described. The distribution of *M. victoria* Essig is extended to California and Idaho where it lives on *A. concolor*.

*Key Words:* Aphididae, *Mindarus*, aphid, new species

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Aphids of the genus *Mindarus* are mon-oecious, needle feeders on *Abies*, *Keteleeria* or *Picea*. In this holarctic genus are five fossil and five extant species. Heie (1967) discusses the living species in relation to the fossils and provides a key to eight species.

The literature reports three species from North America: *Mindarus abietinus* Koch, *M. obliquus* (Cholodkovsky) and *M. victoria* Essig. *Mindarus obliquus* lives on *Picea* and the latter two live on *Abies*. Because of the morphological similarity between *obliquus* and *abietinus* they have been identified primarily on the basis of the host on which they were collected. Robinson and Chen (1969) found differences between the chromosomes of *Mindarus* from *Picea* and those from *Abies*, and Carter and Eastop (1973) found it possible to separate *Mindarus* collected in Britain from these two hosts by plotting the number of sensoria on the third antennal segment against the length of the segment. *Mindarus victoria* has been re-

corded only from *Abies grandis* in the type locality, Vancouver Island, British Columbia, Canada (Smith and Parron 1978).

The life cycle of *Mindarus abietinus* is reduced in number of generations and relatively simple. The fundatrices produce either alate sexuparae or apterous viviparae that produce only sexuparae. These second and third generation sexuparae produce males and oviparae which mate and by early summer eggs have been deposited on the host. A period of 9-10 months is spent in the egg stage. The biology and seasonal history of *M. abietinus* has been studied in detail by Varty (1966, 1968). This cycle has been common to all species studied until recent work by Ehler and Kinsey (in press) who found that *Mindarus* living on *Abies concolor* on the west slope of the Sierra Nevada, most particularly pest populations in the United States Forest Service Nursery in Placerville, California, had a life cycle and biology which clearly did not match any

published for *M. abietinus* (Nüsslin 1900, Varty 1966, 1968). This aphid is described below.

#### DATA COLLECTION

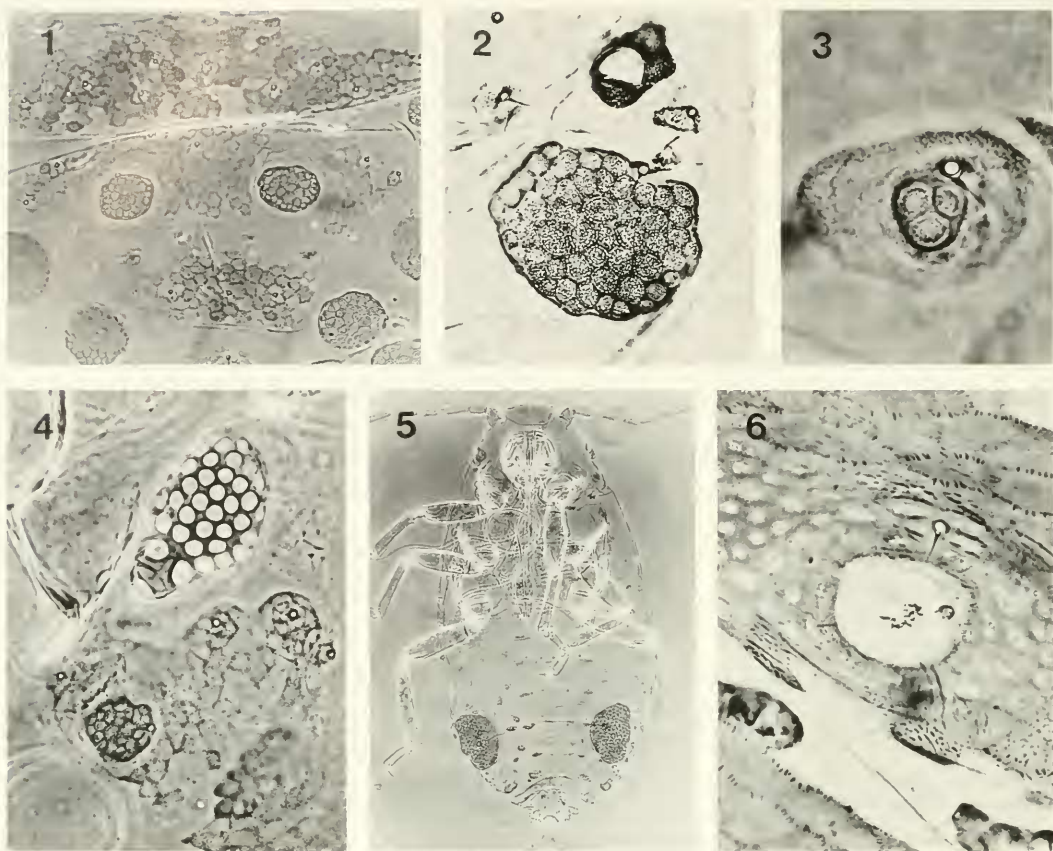
Hundreds of specimens have been provided by Marvin Kinsey (Department of Entomology, University of California, Davis) taken from *Abies concolor* in the Sierra Nevada. In addition he has reared clones from fundatrices through several generations, collecting good series from these clones. Approximately 1500 slides, each containing a minimum of two aphids, have been prepared from this material. Additional specimens were borrowed from several museums.

Measurements were taken of body, wing, hind tibia, antennal segments III, IV, V, VI base and VI process terminalis, ultimate rostral segment, second hind tarsus and counts were made of secondary sensoria on antennal III and IV of alatae, setal counts were made on cauda, ultimate rostral segment, first hind tarsus, subgenital plate, abdominal tergite VIII and scape. The distribution of wax gland plates was recorded on apterous female morphs. Measurements were made with the use of a drawing tube on a Zeiss® microscope extending out over a Zidas® digitizing pad. With this system it is possible to make measurements accurate to three decimal places using a 16× or greater objective.

Wax gland plates (WGP) have not previously been used to discriminate between species of *Mindarus*. They are found on fundatrices, apterae, oviparae and nymphs. They are irregularly shaped, heavily sclerotized plates ranging from circular to oval on which are located groups of cells (Fig. 1). The structure of these cells under high magnification is very regular, appearing much like a sieve (Fig. 2). Foottit and Richards (1993) call these cells "margined cribriform discs" and WGP "clusters of emarginate cribriform discs." Sometimes the plate is only lightly sclerotized (especially in ovi-

parae) but a cluster of closely associated clearly defined cells will still define WGP in such cases. The number of cells in a WGP can vary from one to over a hundred (Fig. 3). Each gland is accompanied by a setae which is located on the anterior half of its margin. Wax gland plates may be found on the head, thorax, abdomen and subanal plate. Typically there are a pair on the front of the head and a pair on the anal plate. Those on the thorax and abdomen may be assigned to paired marginal, dorsolateral and submedian lines (terminology for these lines after Foottit and Richards 1993). In slide-mounted specimens the lateral line often appears to be ventral. These can be expressed as a formula which is maximally 6.6.6:6.6.6.6.6.6.4. The first three numbers refer to number of WGP on the thoracic segments and the later seven refer to the WGP on the first seven abdominal segments. Unless otherwise indicated a 2 means that there are 2 marginal WGP present, a 4 means that there are 2 marginal and 2 dorsolateral WGP, and a 6 means that there are 2 marginal, 2 dorsolateral and 2 submedian WGP on that segment. No specimens have been seen with more than 4 WGP on abdominal segment VII. WGP on the prothorax are usually easy to see and appear to be located on the head due to the fusion of head and prothorax in *Mindarus* (Fig. 4). Diagrammatic representations of the wax gland distribution on various species is shown in Fig. 7. Although there is intraspecific variation, within a range, the distribution patterns seem to hold. The formula for *M. victoria* is almost invariant on specimens seen from several locations in California and British Columbia taken over several years.

Oviparae have two large wax producing structures located on the abdominal venter (Fig. 5). These have somewhat different structure than WGP in that the entire surface, with the exception of a central pore, is glandular with fine lines creating a matrix of cells of variable shape.



Figs. 1-6. 1, Abdominal tergites V, VI and VII of *M. kinseyi* aptera showing wax gland plates with distinct sclerotized outer ring. 2, High magnification of wax gland plate of aptera of *M. kinseyi* showing sieve-like structure within cells. Siphuncular pore and associated sclerite shown at top of photo. 3, A small wax gland plate containing only three cells. 4, Wax gland plate on prothorax posterior to eye of *M. kinseyi* aptera. 5, Ovipara of *M. kinseyi* showing paired ventral wax glands found on abdominal venter of all *Mindarus* oviparae. 6, Abdominal tergite VI of *M. kinseyi* alata showing membranous wax gland completely embedded in sclerite. Note adjacent glandular areas.

Most of the sclerotization on the dorsum of the body in both apterae and alatae contains less organized glandular areas usually surrounding a seta. These areas are most likely wax producing glands without the discrete structure of the WGP's discussed above.

Although present in alatoid nymphs, wax gland plates as described above are not present in alatae. On the abdomen of alatae at the locations where WGP's would be expected in apterae, there are membranous areas with a dark central spot and a seta (Fig. 6). In some cases under high magni-

fication fine radial lines can be seen around the central spot. The submedian pair of these membranous areas is often embedded in the posterior edge of the sclerotic bands on each tergite (Fig. 8). The dorsolateral and marginal rows are indicated only by the darkened pore and associated seta and are often very difficult to see. Since alatae have some abdominal wax, usually appearing as transverse bands, and these structures are located where WGP's are in nymphs and apterae, it may be that they are wax producing glands. I have been unable to find a name for these



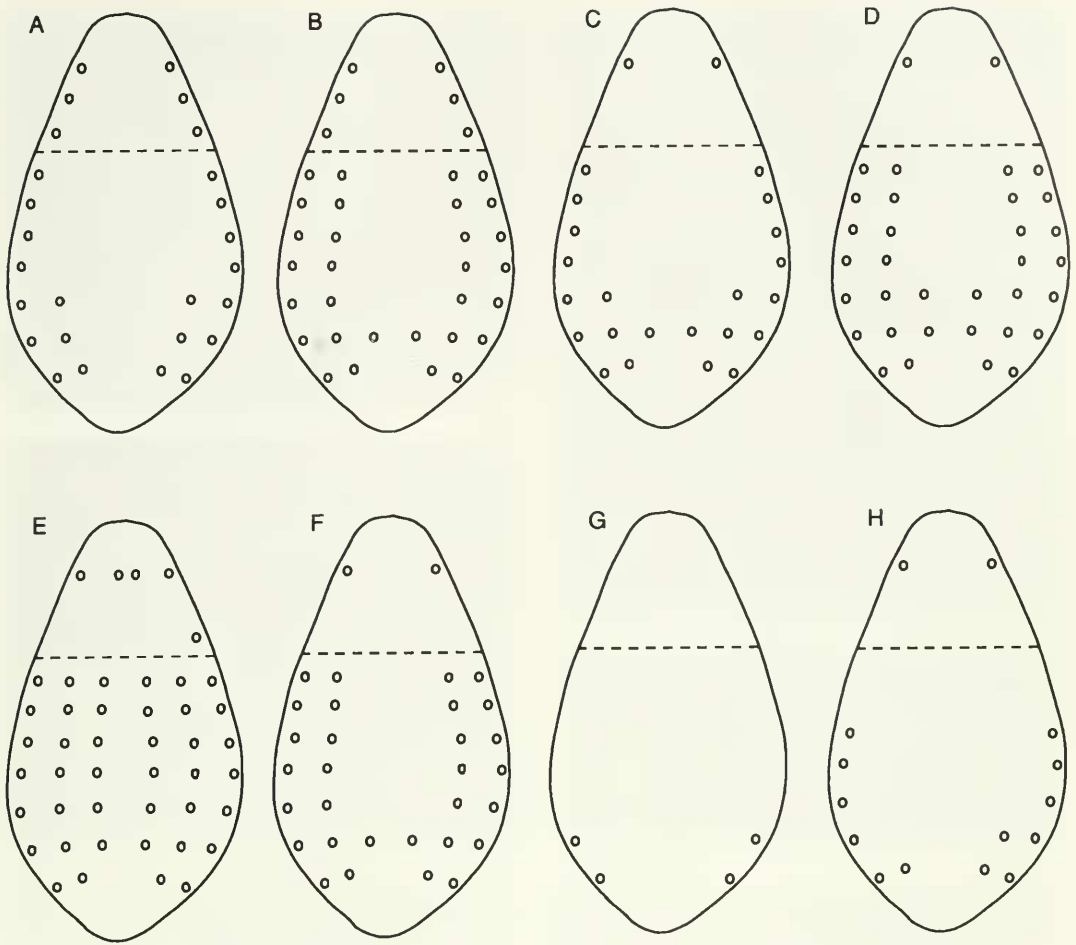


Fig. 7. Diagrammatic representation of apterous morph of *Mindarus* showing paired marginal, dorsolateral and submedian lines of wax gland plates as observed in the following species: A & B, minimum and maximum distribution seen on *M. kinseyi* fundatrices; C & D, minimum and maximum distribution seen on *M. kinseyi* apterae; E, distribution seen on *M. remaudierei* apterae; F, distribution seen on *M. victoria* apterae; G & H, minimal and maximal distribution seen on *M. abietinus* apterae.

structures so will call them membranous wax glands (MWGs).

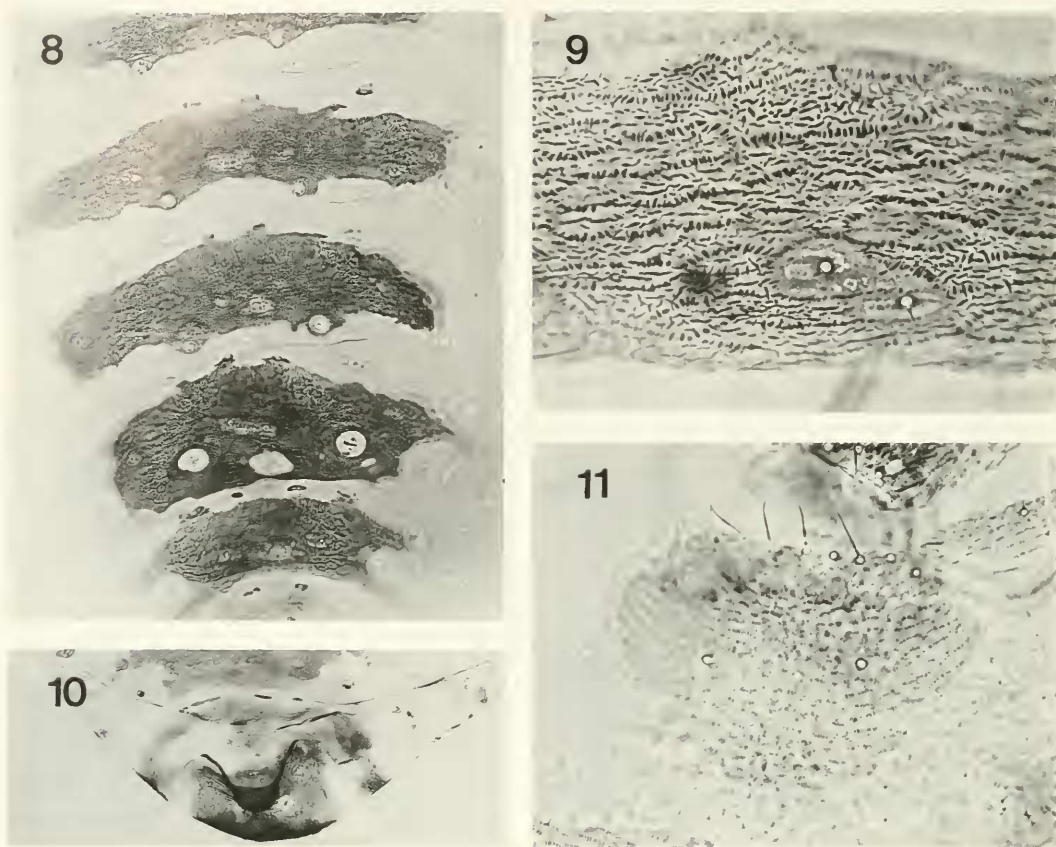
### *Mindarus* Koch 1857

Detailed generic descriptions are given in Heie (1980) and Foottit and Richards (1993) and will not be repeated here. *Mindarus* is the only genus in the subfamily Mindarinae. It is separated from most other aphids by the presence of ventral wax glands in oviparous females and the pterostigma in alatae

extends to the tip of the wing. Males and oviparae are mostly much smaller than viviparous morphs. In apterous morphs there is no visible separation between the head and prothorax. Eyes in fundatrices, oviparae and males consist only of triommatidia while apterae have compound eyes.

Only two named species, *Mindarus japonicus* Takahashi (1931) and *M. keteleerifoliae* Zhang and Zhong (1984), have not been recorded from North America and will not be covered in this paper.





Figs. 8–11. 8, Abdomen of *M. kinseyi* alata showing maximum level of sclerotization and also membranous wax glands associated with posterior edge of sclerites on anterior segments. 9, Dorsal abdominal sclerite of *M. kinseyi* alata showing irregular transverse sculpturing. 10, Cauda shape and size typical of *M. kinseyi* alata. 11, Subgenital plate of *M. kinseyi* alata showing paired setae located on approximate midline of plate.

#### *Mindarus abietinus* Koch

Except for *Mindarus victoria*, specimens of *Mindarus* from *Abies* spp. in North America have been identified and referred to as *M. abietinus*. Based on the morphology of the alatae there is little reason to doubt this. A comparison of the fundatrices and apterae suggests otherwise. Apterae and fundatrices from Europe have a limited distribution of wax gland plates. Dr. G. Remaudière (Museum National D'Histoire Naturelle, Paris) and Dr. R. Blackman (Natural History Museum, London) kindly examined additional fundatrices and apterae in their collection, and confirm this general

pattern of reduction in WGP in *M. abietinus*. The formula for WGP ranged from 0.0.0:0.0.0.0.0.2.2 to 0.0.0:0.0.2.2.2.3.4. Dr. Remaudière has two apterae from Greece with two "very small" WGP on the prothorax which have the formula 2.0.0:0.0.0.2.2.2.2. This is in considerable contrast to the patterns seen in fundatrices and apterae from North America (Fig. 7). I have examined several hundred fundatrices and apterae from multiple years, hosts, distributions and elevations and have yet to find one without at least one pair of lateral WGP on the prothorax and, with the exception of one specimen, all have a complete paired lateral line on the first seven abdominal seg-

ments. The paucity of apterae of *abietinus* in European collections is also in contrast to the abundance of apterae here. With the exception of the aphids studied by Varty (1966, 1968) the number of offspring of the fundatrices (based on collections I have made and those sent to me) which are apterous is significant, reaching nearly 100% in some cases. Much additional work needs to be done but I believe that none of the material I have seen, at least from western North America, is *M. abietinus*.

***Mindarus kinseyi*, n. sp.**

**Fundatrix**

*Color in life:* Pale green, mature specimens covered with filamentous wax, especially laterally and posteriorly. Color of fundatrices and other forms from Ehler and Kinsey (in press).

*Morphology:* Apterous. Eyes only triommatidia, however some specimens examined that are considered fundatrices have a few facets in addition to the triommatidia. Body oval, enlarging gradually from head to abdominal segment IV then rounding to caudal region. Head, scape and pedicel smooth, antennal segments III–VI with gradually increasing density of spiculose imbrications. Head and prothorax fused. Rostrum reaching abdominal segment II, ultimate rostral segment gradually tapering to tip with convex sides. Dorsum of thorax and abdomen smooth with sclerotized areas appearing granular, on posterior segments with irregular transverse lines of spicules. Trochanters and femora fused, joint indicated only by a slight ventral crease. Legs smooth through femora, tibiae lightly spiculose on distal half, second tarsal segment with spiculose imbrications. Cauda slightly raised, transverse ridge. Subgenital plate with spiculose imbrications. Without siphunculi. Setation: Setae very sparse, and short ( $<0.015$  mm). Dorsal setae on a sclerite or edge of a gland. Ultimate rostral segment with 0–2 accessory setae. Cauda with 2 setae. Subgenital plate with 2 setae on

anterior margin and 7–14 scattered along posterior, some specimens with 2 additional setae on midline of plate.

*Sclerotization* (Fig. 12): Intensity of sclerotization varies from pale to medium tan. Head with one central sclerite covering middle of vertex and front but not reaching antennal sockets or eyes. Antennae with scape, pedicel, V and VI and distal  $\frac{1}{3}$  of segment IV darker than segment III and basal  $\frac{1}{3}$  of IV. Paired sclerites on prothorax extend onto posterior of head, mesad of triommatidia. Prothorax with two pairs of small submedian sclerites. Meso- and meta-thorax, and abdominal tergites I–III (IV) each with a row of small, irregularly shaped sclerites. Abdominal tergites (IV), V–VII with sclerotized areas which are highly varied in size and usually extending across mid-dorsal line especially on the latter two segments. Tergite VIII with a narrow sclerotic band most often divided into a median and two lateral sections. Cauda, subanal plate and subgenital plate lightly sclerotized. Legs more or less evenly sclerotized throughout.

*Wax gland plates:* Formula ranging from 2.2.2:0.2.2.2.2.4.4 to 2.2.2:4.4.4.4.4.6.4 (Fig. 7A & B).

*Size:* Summary of measurements given in Table 1.

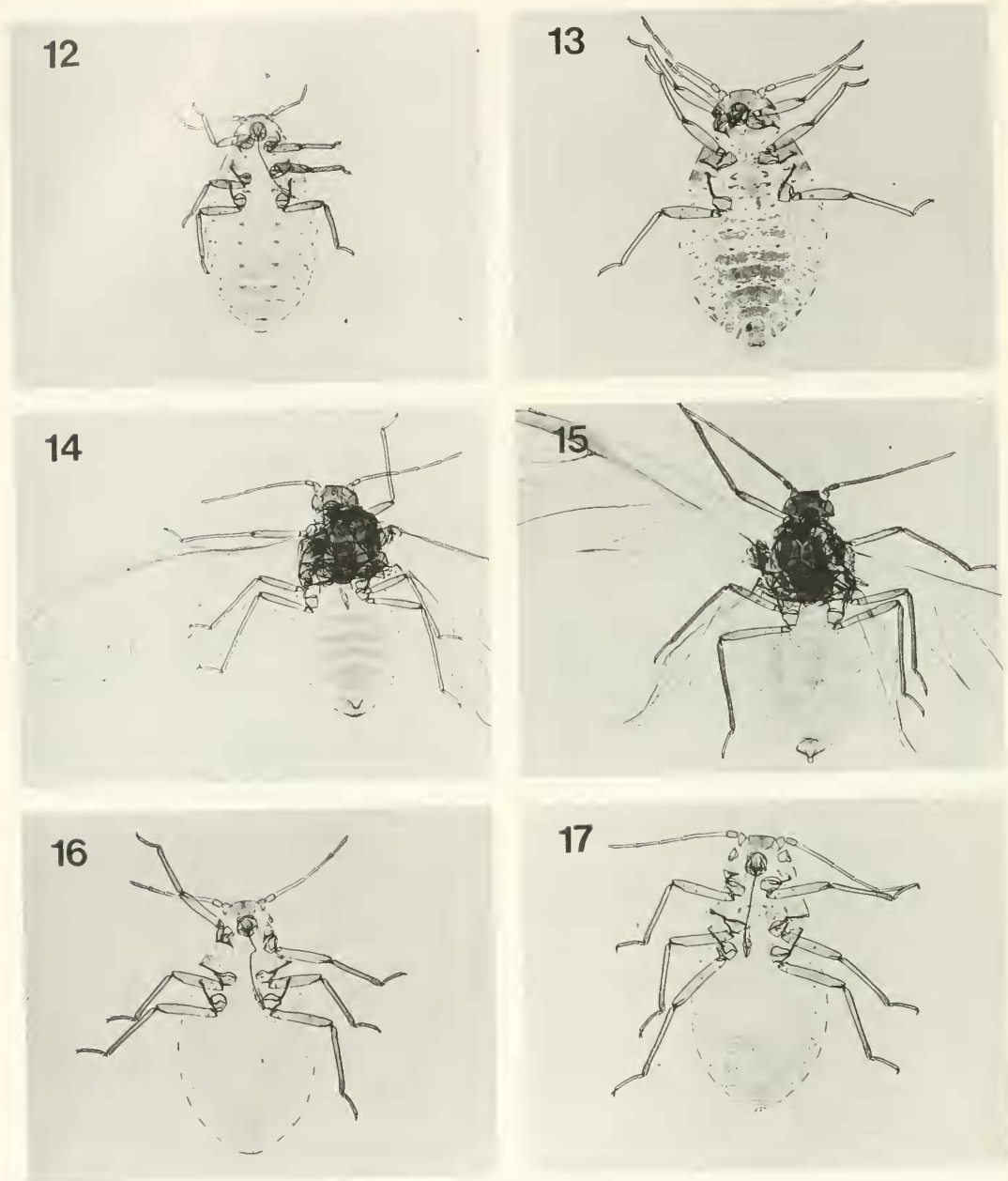
Apterae and alatae are divided into two categories in the description below. These categories, based on date of collection, roughly correspond to observed differences in biology noted between spring and later generations of both morphs (Ehler and Kinsey in press).

**Aptera (second and third generation)**

Description and measurements based on specimens collected in May and June.

*Color in life:* Body pale green covered with a light wax pulverulence which increases with age. Posterior and lateral areas of abdomen can be covered with long wax filaments extruded from wax glands.

*Morphology:* Compound eyes present. Body enlarged gradually from narrow head



Figs. 12-17. 12, Fundatrix of *M. kinseyi*. 13, Apterous of *M. kinseyi* showing close to maximum level of sclerotization. 14, Alata of *M. kinseyi* showing a moderate level of sclerotization on abdomen. 15, Alata of *M. victoria*. 16, Fundatrix of *M. victoria*. 17, Apterous of *M. victoria*.

to mid abdomen rounding smoothly to blunt caudal region; dorsum smooth with faint network of spiculate lines on abdominal tergite VIII. Head and thorax fused, ap-

pearing as one unit. Rostrum reaching abdominal segment III, ultimate rostral segment gradually tapering to blunt tip. Antennae six-segmented without secondary



sensoria, scape and pedicel smooth, flagellum increasingly spiculose distally. Legs smooth, second tarsi with light spiculose imbrications. Cauda slightly elevated, transversely elongate. Siphunculi small rimmed pores sometimes surrounded by a small sclerotic area. Subgenital plate usually rugose and always spiculate. Setation: Setae on body sparse, and short ( $<0.015$  mm). Dorsal setae all on a sclerite or on the edge of a gland. Ultimate rostral segment with 2 accessory setae, rarely 1 or 0. Subgenital plate with 2 setae near middle of anterior margin and (5) 8–14 scattered along posterior margin. Some specimens with an additional smaller pair in the middle of the plate or an additional smaller setae on either side of the middle pair on the anterior margin.

*Sclerotization* (Fig. 13): On body from medium to light tan. Head with wide, parallel sided, median sclerite covering vertex and front, median suture indicated on both vertex and front. Irregularly shaped sclerotic areas on posterior of head and prothorax. Sclerites on meso- and metathorax and tergites I and II small, scattered across segment in an irregular line, gradually increasing in size on tergites III and IV and tergites V–VII each with transverse band; tergite VIII with narrow band divided into submedian and two lateral sections. Scape and pedicel concolorous with central head sclerite, distal tip of III and  $\frac{1}{2}$  of IV slightly darkened, V and VI darker than head. Legs evenly tanned, coxae and trochanters lighter.

*Wax gland plates*: Formula commonly ranging from 2.0.0:2.2.2.2.4.5.4 to 2.0.0:4.4.4.4.6.6.4 (Fig. 7C & D). One specimen seen without a complete paired marginal line of glands and one specimen seen with thoracic formula 2.2.2.

*Size*: Summary of measurements given in Table 1.

Alata (second and third generation)

Descriptions and measurements based on specimens collected in May and June.

*Color in life*: Body light to medium green, shiny in recently molted adults becoming covered with a light pulverulence in mature specimens.

*Morphology*: Head clearly separate from narrow prothorax, ocelli on vertex located on anterior-mesal margin of compound eyes, ocellus on front located at base of indistinct median suture. Rostrum reaching to abdominal segment II, ultimate rostral segment with slightly convex sides gradually tapering to rounded tip. Antennae six-segmented with 8–23 (mean = 14.5, var. = 6.6) secondary sensoria on segment III and 0–4 (mean = 1.9, var. = 0.7) on segment IV, scape pedicel and III smooth, IV–VI with spiculose imbrications. Abdomen gradually widening from pterothorax to abdominal segment V then tapering to more pointed abdomen than apterae, prothorax and membranous areas of dorsum smooth, dorsal lobes of pterothorax with reticulate sculpturing, sclerotized bands on abdominal segments I–VII with irregular transverse sculpturing (Fig. 9). Legs smooth except for anterior surface of femora and second tarsi which have spiculose imbrications. Siphunculi rimmed pores, rarely absent, sometimes surrounded by a small sclerite. Cauda rugose, subtriangular with rounded tip, usually wider than long (Fig. 10). Subgenital plate spiculose. Setation: On body sparse as in apterae and very short ( $<0.01$  mm). Abdominal segments with a row of setae on the sclerotic band. Setae on tibiae  $<$  half tibial diameter. Ultimate rostral segment with 2, rarely 1 or 0, accessory setae. Subgenital plate usually with 2 large setae located near midline and 8–15 scattered along posterior margin (Fig. 11). Some specimens with a second smaller pair between midline and posterior group or one on each side of median pair.

*Sclerotization* (Fig. 14): Head and pterothorax heavily sclerotized, prothorax pale. Scape and pedicel concolorous with head and darker than flagellum which is evenly sclerotized. Coxae and trochanters pale, femora gradually darkening distally, tibiae

Table 1. Measurements for *Mindarus* spp. For each character the range is given, the mean is in boldface followed by the variance. The n values for each morph vary because on some of the specimens certain characters were not measurable. Length of antennal segment VI is not separated into base and process terminalis for the oviparae and males. All measurements are in mm.

|                       | Body                 | Wing                | Hind Tibia           | Antennal Segments    |                      |
|-----------------------|----------------------|---------------------|----------------------|----------------------|----------------------|
|                       |                      |                     |                      | III                  | IV                   |
| <i>M. kinseyi</i>     |                      |                     |                      |                      |                      |
| Fundatrices           | 1.42-1.80            |                     | 0.253-0.431          | .115-.198            | 0.054-0.096          |
| n = 17-23             | <b>1.62</b> , 0.009  |                     | <b>0.306</b> , 0.003 | <b>0.149</b> , 0.000 | <b>0.073</b> , 0.000 |
| Apterae               |                      |                     |                      |                      |                      |
| May-June              | 1.35-2.27            |                     | 0.319-0.560          | 0.174-0.332          | 0.087-0.170          |
| n = 116-119           | <b>1.84</b> , 0.027  |                     | <b>0.468</b> , 0.002 | <b>0.275</b> , 0.001 | <b>0.136</b> , 0.000 |
| July-Sept.            | 1.09-2.14            |                     | 0.292-0.577          | 0.155-0.330          | 0.074-0.168          |
| n = 129-131           | <b>1.56</b> , 0.042  |                     | <b>0.416</b> , 0.003 | <b>0.243</b> , 0.001 | <b>0.118</b> , 0.000 |
| Alatae                |                      |                     |                      |                      |                      |
| May-June              | 1.28-2.90            | 1.61-3.47           | 0.453-0.925          | 0.195-0.475          | 0.102-0.242          |
| n = 199-212           | <b>2.08</b> , 0.115  | <b>2.58</b> , 0.160 | <b>0.704</b> , 0.008 | <b>0.356</b> , 0.002 | <b>0.187</b> , 0.001 |
| July-Nov.             | 1.02-2.83            | 1.30-3.28           | 0.346-0.864          | 0.173-0.439          | 0.098-0.231          |
| n = 154-156           | <b>1.79</b> , 0.090  | <b>2.26</b> , 0.147 | <b>0.601</b> , 0.010 | <b>0.307</b> , 0.002 | <b>0.169</b> , 0.001 |
| Oviparae              | 0.074-1.00           |                     | 0.131-0.196          | 0.040-0.066          | 0.016-0.043          |
| n = 68-69             | <b>0.88</b> , 0.002  |                     | <b>0.161</b> , 0.000 | <b>0.051</b> , 0.000 | <b>0.031</b> , 0.000 |
| Males                 | 0.52-0.66            |                     | 0.126-0.174          | 0.050-0.090          | 0.029-0.051          |
| n = 35-36             | <b>0.60</b> , 0.001  |                     | <b>0.150</b> , 0.000 | <b>0.065</b> , 0.000 | <b>0.040</b> , 0.000 |
| <i>M. remaudierei</i> |                      |                     |                      |                      |                      |
| Apterae               | 2.01-2.34            |                     | .510-.550            | 0.295-0.314          | 0.107-0.127          |
| n = 4                 | <b>2.16</b> , 0.019  |                     | <b>0.528</b> , 0.000 | <b>0.302</b> , 0.000 | <b>0.116</b> , 0.000 |
| Alatae                | 2.05-3.00            | 2.91-3.48           | 0.706-0.851          | 0.449-0.510          | 0.171-0.210          |
| n = 15                | <b>2.43</b> , 0.063  | <b>3.23</b> , 0.033 | <b>0.808</b> , 0.002 | <b>0.490</b> , 0.000 | <b>0.192</b> , 0.000 |
| <i>M. victoria</i>    |                      |                     |                      |                      |                      |
| Fundatrices           | 1.67-2.20            |                     | 0.382-0.565          | 0.207-0.312          | 0.108-0.169          |
| n = 40                | <b>1.96</b> , 0.018  |                     | <b>0.512</b> , 0.001 | <b>0.274</b> , 0.000 | <b>0.140</b> , 0.000 |
| Apterae               | 1.76-2.47            |                     | 0.537-0.688          | 0.287-0.415          | 0.158-0.218          |
| n = 32-33             | <b>2.08</b> , 0.031  |                     | <b>0.620</b> , 0.002 | <b>0.368</b> , 0.001 | <b>0.187</b> , 0.000 |
| Alatae                | 1.67-2.85            | 2.13-3.52           | 0.562-0.870          | 0.333-0.484          | 0.168-0.260          |
| n = 47-50             | <b>2.36</b> , 0.070  | <b>3.01</b> , 0.106 | <b>0.785</b> , 0.005 | <b>0.419</b> , 0.001 | <b>0.218</b> , 0.000 |
| Oviparae              | 1.11-1.94            |                     | 0.307-0.494          | 0.159-0.307          | 0.076-0.152          |
| n = 39-40             | <b>1.53</b> , 0.033  |                     | <b>0.410</b> , 0.002 | <b>0.241</b> , 0.001 | <b>0.119</b> , 0.000 |
| Males                 | 0.769-0.889          |                     | 0.226-0.275          | 0.091-0.139          | 0.051-0.064          |
| n = 11                | <b>0.808</b> , 0.001 |                     | <b>0.252</b> , 0.000 | <b>0.114</b> , 0.000 | <b>0.058</b> , 0.000 |

and tarsi evenly sclerotized. Abdominal tergites I-VII with transverse bands, decreasing in size on anterior segments. Tergite VIII with narrow band which is sometimes incomplete forming a median and two marginal sections. Cauda and anal region darker than unevenly sclerotized subgenital plate.

*Membranous wax glands:* The most common arrangement seen is two on abdominal segment VI within the sclerotic band and two on segment VII that are not contained completely within the band. Fig. 8 shows the maximum development of these glands in spring alatae.

Table 1. Extended.

| Antennal Segments                   |                                     |                                     | Ultimate<br>Rostral Seg.            | Second<br>Hind Tarsus               | Antennal<br>Flagellum               |
|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| V                                   | VI base                             | VI pt                               |                                     |                                     |                                     |
| <i>M. kinseyi</i>                   |                                     |                                     |                                     |                                     |                                     |
| 0.083–0.108<br><b>0.092</b> , 0.000 | 0.091–0.114<br><b>0.101</b> , 0.000 | 0.020–0.030<br><b>0.026</b> , 0.000 | 0.048–0.070<br><b>0.057</b> , 0.000 | 0.102–0.137<br><b>0.118</b> , 0.000 | 0.386–0.540<br><b>0.440</b> , 0.002 |
| 0.095–0.168<br><b>0.136</b> , 0.000 | 0.092–0.152<br><b>0.127</b> , 0.000 | 0.024–0.039<br><b>0.032</b> , 0.000 | 0.051–0.080<br><b>0.069</b> , 0.000 | 0.128–0.194<br><b>0.168</b> , 0.000 | 0.484–0.832<br><b>0.706</b> , 0.005 |
| 0.087–0.174<br><b>0.127</b> , 0.000 | 0.088–0.168<br><b>0.122</b> , 0.000 | 0.023–0.042<br><b>0.031</b> , 0.000 | 0.051–0.083<br><b>0.066</b> , 0.000 | 0.119–0.199<br><b>0.159</b> , 0.000 | 0.336–0.873<br><b>0.638</b> , 0.007 |
| 0.124–0.243<br><b>0.192</b> , 0.001 | 0.110–0.203<br><b>0.158</b> , 0.000 | 0.023–0.043<br><b>0.032</b> , 0.000 | 0.058–0.087<br><b>0.071</b> , 0.000 | 0.125–0.227<br><b>0.187</b> , 0.000 | 0.554–0.150<br><b>0.925</b> , 0.111 |
| 0.114–0.231<br><b>0.178</b> , 0.001 | 0.104–0.190<br><b>0.149</b> , 0.000 | 0.021–0.040<br><b>0.031</b> , 0.000 | 0.056–0.081<br><b>0.067</b> , 0.000 | 0.125–0.208<br><b>0.172</b> , 0.000 | 0.513–1.076<br><b>0.834</b> , 0.011 |
| 0.032–0.063<br><b>0.050</b> , 0.000 | 0.071–0.099<br><b>0.082</b> , 0.000 |                                     | 0.034–0.049<br><b>0.044</b> , 0.000 | 0.057–0.077<br><b>0.067</b> , 0.000 | 0.160–0.267<br><b>0.214</b> , 0.000 |
| 0.036–0.069<br><b>0.050</b> , 0.000 | 0.073–0.104<br><b>0.086</b> , 0.000 |                                     | 0.030–0.039<br><b>0.033</b> , 0.000 | 0.056–0.071<br><b>0.064</b> , 0.000 | 0.198–0.303<br><b>0.241</b> , 0.001 |
| <i>M. remaudierei</i>               |                                     |                                     |                                     |                                     |                                     |
| 0.150–0.166<br><b>0.157</b> , 0.000 | 0.141–0.158<br><b>0.146</b> , 0.000 | 0.031–0.040<br><b>0.36</b> , 0.000  | 0.088–0.096<br><b>0.091</b> , 0.000 | 0.157–0.179<br><b>0.168</b> , 0.000 | 0.732–0.805<br><b>0.757</b> , 0.001 |
| 0.197–0.240<br><b>0.218</b> , 0.000 | 0.162–0.190<br><b>0.174</b> , 0.000 | 0.031–0.042<br><b>0.037</b> , 0.000 | 0.087–0.102<br><b>0.093</b> , 0.000 | 0.172–0.193<br><b>0.183</b> , 0.000 | 0.930–1.164<br><b>1.098</b> , 0.004 |
| <i>M. victoria</i>                  |                                     |                                     |                                     |                                     |                                     |
| 0.119–0.192<br><b>0.168</b> , 0.000 | 0.117–0.190<br><b>0.164</b> , 0.000 | 0.021–0.029<br><b>0.025</b> , 0.000 | 0.060–0.078<br><b>0.072</b> , 0.000 | 0.141–0.219<br><b>0.198</b> , 0.000 | 0.576–0.857<br><b>0.772</b> , 0.003 |
| 0.187–0.231<br><b>0.207</b> , 0.000 | 0.173–0.207<br><b>0.190</b> , 0.000 | 0.022–0.034<br><b>0.028</b> , 0.000 | 0.070–0.083<br><b>0.077</b> , 0.000 | 0.207–0.247<br><b>0.234</b> , 0.000 | 0.850–1.079<br><b>0.980</b> , 0.003 |
| 0.186–0.276<br><b>0.237</b> , 0.000 | 0.166–0.242<br><b>0.209</b> , 0.000 | 0.026–0.041<br><b>0.032</b> , 0.000 | 0.067–0.085<br><b>0.077</b> , 0.000 | 0.184–0.266<br><b>0.234</b> , 0.000 | 0.879–1.247<br><b>1.116</b> , 0.007 |
| 0.099–0.183<br><b>0.147</b> , 0.000 | 0.127–0.205<br><b>0.170</b> , 0.000 |                                     | 0.061–0.079<br><b>0.068</b> , 0.000 | 0.140–0.199<br><b>0.178</b> , 0.000 | 0.478–0.830<br><b>0.676</b> , 0.000 |
| 0.079–0.093<br><b>0.085</b> , 0.000 | 0.115–0.135<br><b>0.124</b> , 0.000 |                                     | 0.040–0.047<br><b>0.045</b> , 0.000 | 0.108–0.127<br><b>0.121</b> , 0.000 | 0.364–0.402<br><b>0.381</b> , 0.000 |

Size: Summary of measurements given in Table 1.

Aptera  
(late season viviparae and sexuparae)

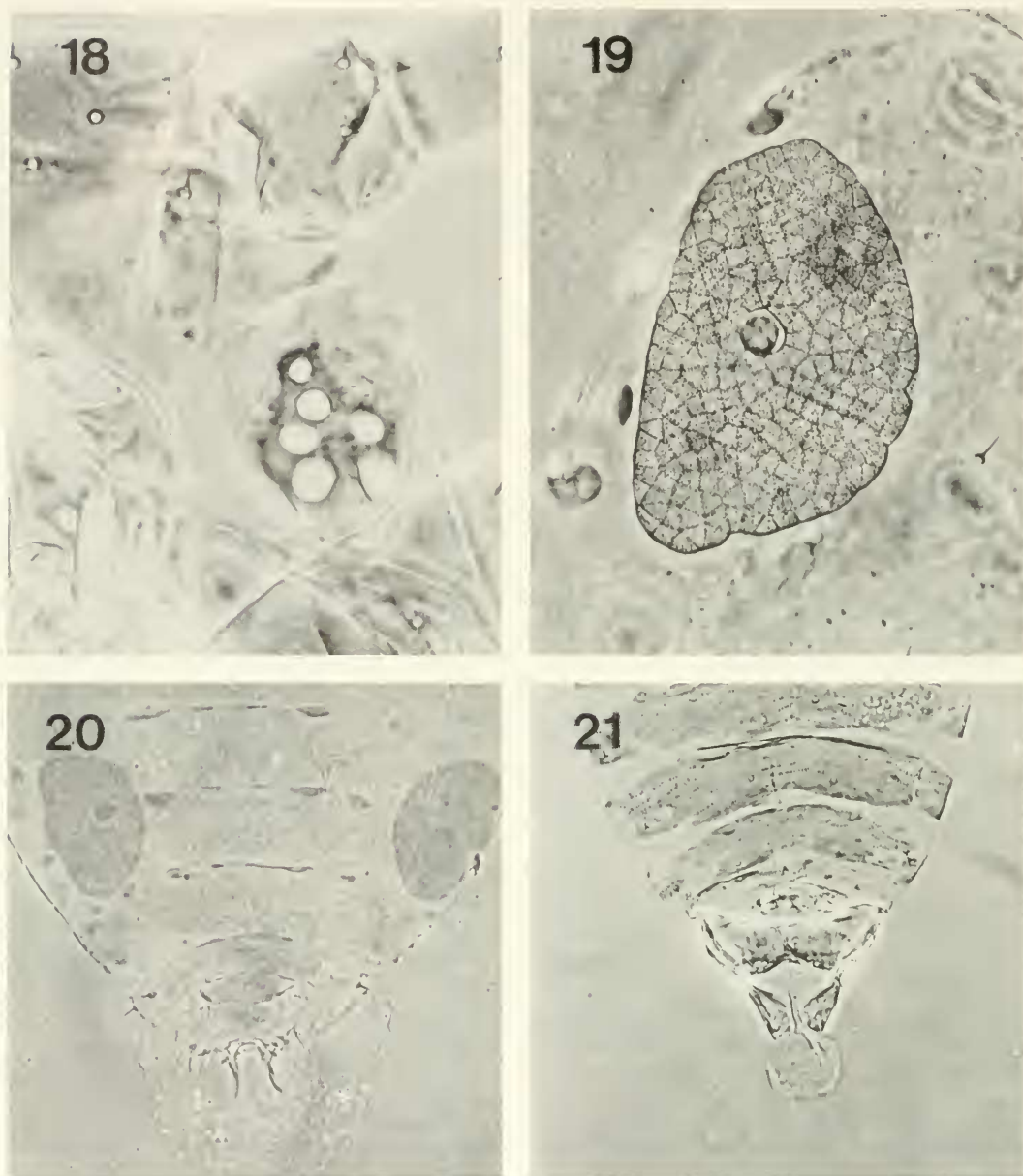
It is not possible to discriminate morphologically between those apterae that pro-

duce viviparous offspring and those producing sexuales. Description and measurements made from specimens collected July through November.

Color in life: Similar to spring apterae.

Morphology: Similar to spring apterae. Eye size is highly variable in this group.





Figs. 18–21. 18, Compound eye of *M. kinseyi* aptera showing reduction in facets common in summer apterae. 19, Magnification of ventral wax gland of *M. kinseyi* ovipara showing combination of mostly triangular and square cells. 20, Genital structure of *M. kinseyi* ovipara. 21, Genital structure of *M. kinseyi* male.

There seems to be a general decrease in number of facets as the season progresses. Not all specimens exhibit this but late summer apterae with only a few facets in addition to the triommatidia are common (Fig.

18). Siphuncular pores generally without a sclerite. Setation: As in spring apterae.

*Sclerotization:* Pattern of sclerotization similar to the apterae described above, however, there is a gradual reduction in size and

intensity of tanning of sclerites as the summer progresses. Specimens collected during the winter show increased darkness and size of sclerites so this variability may be in part a function of temperature. In the most reduced form the entire body is almost completely pale with only the wax glands visible on the abdomen. Sclerites are first lost on anterior segments then bands on tergites V, VI and VII begin to disintegrate into individual pale sclerites, finally becoming very small and almost invisible.

*Wax gland plates:* Formula ranging from 2.0.0:2.2.2.2.4.6.4 to 2.0.0:4.4.4.4.4.6.4.

*Size:* Summary of measurements given in Table 1.

### Alata

(late season viviparae and sexuparae)

It is not possible to discriminate morphologically between those alatae that produce viviparous offspring and those that produce sexuales. Descriptions and measurements made from specimens collected July through November.

*Color in life:* Similar to spring alatae.

*Morphology:* Similar to spring alatae. There is a gradual decrease in size of alatae throughout the season (Table 1). Siphuncular pores may not have an associated sclerite, sometimes absent. Setation: As in spring alatae.

*Sclerotization:* This group shows tremendous range of presence and intensity of sclerotization. Specimens developing in July and August range from the sclerotization of spring alatae to a point where virtually none of the sclerotic bands on the abdominal segments are visible and the pterothorax and appendages are pale. Specimens collected in September through February are more likely to show sclerotization intensity of spring generations. This seasonal variation in sclerotization is similar to that seen in apterae.

*Wax glands:* Wax production areas appear to be associated with sclerites and since the sclerites are greatly reduced or absent the amount of glandular area on the dorsum

appears to be much reduced in some specimens. The paired MWGs on abdominal segments VI and VII are usually not contained within the sclerotized bands.

*Size:* Summary of measurements given in Table 1.

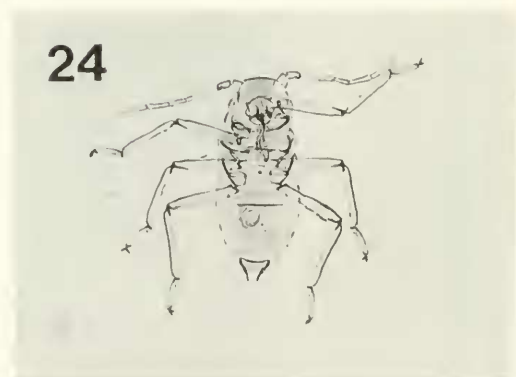
### Ovipara

*Color in life:* Entire body yellow to gold. Not as covered with wax as are other apterous morphs.

*Morphology:* Apterous. Eyes only triommatidia. Body elongate oval appearing parallel sided from mesothorax to abdominal segment V, dorsum smooth with faint spiculate lines visible on posterior abdominal segments. Head and prothorax fused, appearing as one unit. Rostrum reaching abdominal segment IV, ultimate rostral segment blunt with slightly convex sides. Antennae six-segmented without secondary sensoria, segments I–IV smooth, V and VI with a few spiculate imbrications. Cauda only slightly elevated. Siphuncular pores absent. Hind tibia with (1) 2–8 (11) scent plaques (Fig. 23). A modified genital structure present (Fig. 20) consisting of a base and two posteriorly directed arms. Setation: Much reduced as in apterae. Ultimate rostral segment with 2 sometimes 1 or 0 accessory setae. Subgenital plate with 6–10 setae along posterior margin, 2 near anterior margin.

*Sclerotization* (Fig. 23): Head with median parallel-sided sclerite extending over vertex and front but not enclosing base of antennae or triommatidia. Median suture visible on front but not vertex. Front with a pair of wax gland plates. Antennae with scape, pedicel, segments V and VI somewhat darker than head, III and IV pale. Legs evenly sclerotized and only slightly darker than antennae. Hind tibiae with 4–13 irregularly shaped scent plaques. No dorsal sclerites visible on thorax or abdomen. Cauda light tan. Subgenital plate at most lightly sclerotized, indicated by setal arrangement.

*Wax gland plates:* Formula ranging from



Figs. 22–25. 22, Ovipara of *M. victoria*. 23, Ovipara of *M. kinseyi*. 24, Male of *M. victoria*. 25, Male of *M. kinseyi*.

2.2.2:0.2.2.2.2.3.4 to 2.2.2:2.4.4.4.4.6.4 more variable than in fundatrices and apterae. When present on the first abdominal tergite the two glands are in the dorsolateral line, not the marginal as in apterae. Two large, asymmetrical glands on the abdominal venter (Fig. 5) produce elongated, straight wax filaments which protrude from the glands perpendicular to the body. These glands are granular in appearance and have a lattice like substructure creating numerous

triangular and square cells (Fig. 19). There is also a central pore in which (0) 2–4 (5) cells are visible.

*Size:* Summary of measurements given in Table 1.

#### Male

*Color in life:* Entire body blue to blue green.

*Morphology:* Apterous. Eyes only triommatidia. Small, elongate oval body almost



parallel sided from mesothorax to abdominal segment V. Head and prothorax fused, appearing as one unit. Rostrum reaching mesocoxae, ultimate rostral segment short, blunt with convex sides. Antennae 6 segmented with secondary sensoria on segments IV (1–2), V (1–3) and VI (2–4); segments I–IV (I–III) smooth, (IV) V–VI with some spiculose imbrications. Trochanter-femoral joint fused, indicated only by faint suture. Legs smooth throughout. Thoracic sclerites smooth, abdominal sclerites increasingly spiculose on posterior segments. Cauda not developed but indicated by two setae. Siphuncular pores absent. A genital structure present (Fig. 21). Setation: Very reduced. Ultimate rostral segment without accessory setae.

*Sclerotization* (Fig. 25): Head sclerotized throughout, thoracic and abdominal segments each with wide transverse band. Scape and pedicel, distal ½ of III, IV, V and VI concolorous with head. Legs evenly dark throughout and only slightly darker than body.

*Wax glands*: No glandular areas observed.

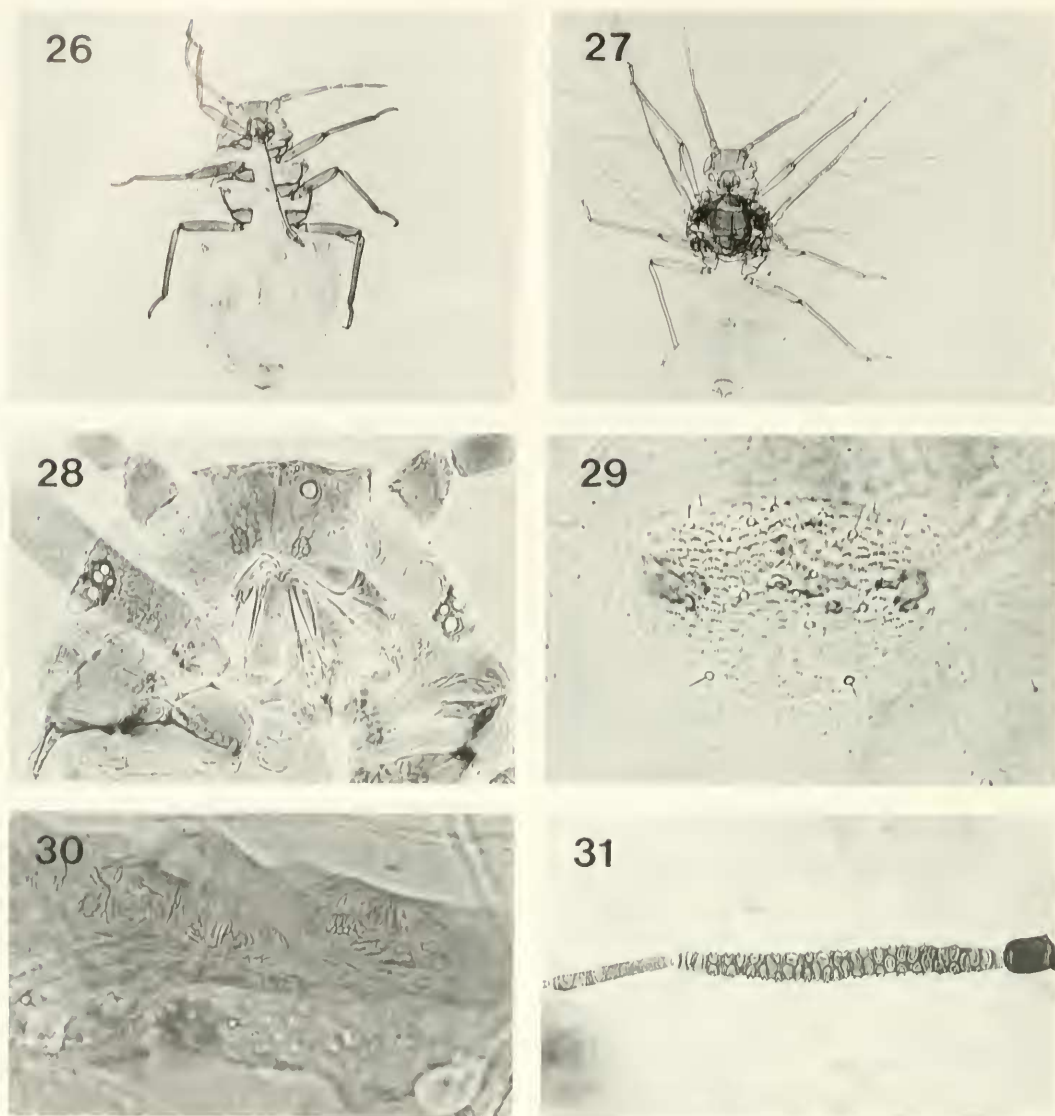
*Size*: Summary of measurements given in Table 1.

*Types*: Holotype, morphotypes and all paratypes collected on *Abies concolor* in California by Marvin Kinsey unless otherwise noted. Holotype: Apter, top specimen circled on slide #92-63-12 with three other apterae. *Abies concolor*, USFS Nursery, Placerville, Eldorado County, California, 14 June 1992, M. Kinsey, deposited at the Illinois Natural History Survey, Champaign, Illinois. Morphotypes: Fundatrix, Cold Springs, Toulumne County, 18 June 1992, M. Kinsey & D. Voegtlin (top specimen circled on slide #92-55-22 with one aptera); alata, Westpoint, Calaveras County, 24 June 1991 (on slide #92-6-1 with aptera); ovipara and male, USFS Nursery, Placerville, Eldorado County, 7 June 1992 (circled on slide #92-61-40 with one other male and ovipara); all deposited at INHS. Paratypes: Ca-

laveras County: Sonora, 26 June 1991, 10 ap., 20 al.; 3 July 1991, 2 fund. West Point, 24 June 1991, 12 ap., 13 al.; 10 July 1991, 5 ap., 19 al. Eldorado County: Camino, 15 May 1990, 5 ap., 1 al., 13 June 1991, 20 ap., 10 al.; 11 September 1990, 16 ap., 18 al. Morgan, 6 June 1991, 10 fund., 16 ap., 15 al. USFS Nursery, Placerville, 24 August 1989, 22 ap., 22 al., L. Ehler; 30 August 1989, 19 ap., 14 al., L. Ehler; 21 June 1990, 11 ap., 11 al.; 30 July 1990, 12 ap., 12 al.; 28 August 1990, 5 ap., 19 al.; 11 September 1990, 12 ap., 8 al.; 28 August 1991, 6 ap., 18 al.; 2 October 1991, 12 ap., 12 al. Sly Park, 25 June 1991, 16 ap., 16 al.; 10 July 1991, 6 ap., 10 al. 40 km S. E. of Sly Park, Eldorado Nat. For., 7 July 1992, 3 ap., 26 al., 12 ovip., 12 male. Plumas County: Grey Eagle, 7 July 1991, 4 ap., 5 al. Siskiyou County: Mt. Shasta, 20 June 1991, 3 ap., 3 al. Tulare County: Peppermint Camp Ground, nr. Johnsondale, 17 June 1992, 2 fund., 4 ap., 29 al., 3 ovip., 3 male, M. Kinsey & D. Voegtlin. Sequoia Kings Canyon N. P., 27 July 1992, 11 ap., 14 al. Toulumne County: Yosemite Institute, 18 June 1992, 7 al., M. Kinsey & D. Voegtlin. Cold Springs, 18 June 1992, 2 fund., 22 ap., 21 al., 5 ovip., 1 male, M. Kinsey & D. Voegtlin. Hardin Flat, 18 June 1992, 2 fund., 5 ap., 16 al., 2 ovip., 4 male, M. Kinsey & D. Voegtlin. Strawberry, 19 June 1992, 2 fund., M. Kinsey & D. Voegtlin. Paratypes will be deposited at the following museums: United States National Museum, Beltsville; The Natural History Museum, London; Museum National D'Histoire Naturelle, Paris; Canadian National Museum, Ottawa, all remaining slides are on deposit at INHS.

*Discrimination*: The biology of this species separates it from all other *Mindarus* species. Fundatrices and apterae can easily be separated from *M. abietinus* by the WGP's (see discussion of *M. abietinus* above). Many alatae have more than one sensoria on antennal segment IV, a condition uncommon in *M. abietinus* but common in *M. obliquus*. The tremendous variabilities in size and





Figs. 26–31. 26, Holotype of *M. remaudierei*. 27, Morphotype of *M. remaudierei*. 28, Head of *M. remaudierei* aptera showing few eye facets in addition to the triommatidion. 29, Subgenital plate of *M. remaudierei* aptera showing paired setae on anterior margin and cluster of setae at midplate. 30, Dorsal abdominal sclerite of *M. remaudierei* aptera showing paired setae on anterior margin and cluster of setae at midplate. 31, Antennal segments III and IV of *M. remaudierei* alata showing large number of secondary sensoria on III.

pigmentation of the alatae make it virtually impossible to separate this morph from *M. abietinus* or *M. obliquus*.

*Etymology:* This species is named after Marvin Kinsey whose careful observations

and field work detailed much of the biology of this species (Ehler and Kinsey in press) and who collected and reared the majority of specimens on which this description is based.

*Mindarus remaudierei*, n. sp.

## Aptera

*Color in life:* Not seen alive.

*Morphology:* Body oval, increasing in width to abdominal segment IV then rounding to caudal region. Eyes only a few facets in addition to the triommatidia (Fig. 28). Head, scape and pedicel smooth, spiculose imbrications gradually increasing from antennal segments III–VI. Two of the four apterae seen with one secondary sensoria on antennal segment III but they have no other indications of alatoity such as small wing buds and large compound eyes. Rostrum reaching abdominal segment II, ultimate rostral segment with gradually tapering slightly convex sides and rounded tip. Head and prothorax fused, smooth as is the remainder of the dorsum. Legs smooth to second tarsi which have spiculose imbrications. Subgenital plate spiculose. Cauda slightly elevated. Siphuncular pore rimmed. Setation: Very sparse and short <0.015 mm. Ultimate rostral segment with 2 accessory setae; cauda with 2 setae; subgenital plate with 20–23 setae arranged with 2 on the anterior half, from 2–6 in the central area and 14–17 along the posterior edge.

*Sclerotization* (Fig. 26): Head with front and much of vertex sclerotized, enclosing antennal sockets but not eyes. Irregular pale sclerotic band extending across prothorax and abdominal segment VIII. Remainder of dorsum clear. Antennae slightly darker than head with only basal  $\frac{1}{3}$ – $\frac{1}{2}$  of segment III lighter. Legs medium brown, darker than antennae with base of femora and trochanters paler. Cauda and subanal plate only slightly darkened. Subgenital plate with irregular dark areas.

*Wax gland plates:* Formula ranging from 4.0.0:5.6.6.6.6.6.4 to 4.0.1:6.6.6.6.6.4 (Fig. 7E). Without a distinct sclerotized ring around each plate. The four on the prothorax are on the submedian and marginal lines. Three of the four specimens have an additional WGP on the vertex.

*Size:* Summary of measurements given in Table 1.

## Alata

*Color in life:* Not seen in life.

*Morphology:* Head smooth with area on vertex posterior to eyes with longitudinal ridges. Antennal scape, pedicel and III smooth, IV–VI imbricated, most imbrications on segments IV and V without spicules, those on VI spiculose. Antennal segment III with 45 to 54, and segment IV with 1–5 secondary sensoria (Fig. 31). Pterothorax rugose. Anterior surface of femora and second tarsi with spiculose imbrications, remainder of legs smooth. Non-sclerotized regions of the abdomen smooth. Sclerotic bands on abdominal segments with limited sculpturing, much less than seen in other *Mindarus* spp. (Fig. 30). Siphuncular pore usually surrounded with a small, pale sclerotized area. Cauda subtriangular with rugose knob at tip, wider than long. Subgenital plate spiculose. Setation: Sparse and short <0.015 mm. Tibial setae < $\frac{1}{2}$  diameter of tibiae. Ultimate rostral segment with 2 accessory setae. Cauda with 2 setae. Subgenital plate with 15–21 setae, 2–4 on anterior half, 0–3 near the middle and 11–15 scattered along the posterior edge.

*Sclerotization* (Fig. 27): Head, scape, pedicel and antennal segment III light amber, IV–VI evenly colored and paler. Pterothorax darker than head. Legs evenly colored, concolorous with head. Bands on abdominal tergites pale, not extending across segment and not visible on some specimens. Cauda and anal plate concolorous with head. Subgenital plate with irregular dark areas usually confined to posterior half.

*Membranous wax glands:* When sclerotic bands are visible on the abdomen the paired submedian line of MWGs is embedded in the posterior edge of these sclerites on abdominal segments I–VI.

*Size:* Summary of measurements given in Table 1.

*Types:* Holotype: Apteræ, right hand specimen indicated on slide with one other apteræ and one nymph (Fig. 26). Taken on *Abies religiosa*, Selva Obscura, 2870 m, Puebla, Mexico, 5 June 1983, A. L. Munoz, collection #265. Morphotype: Alata, same data as holotype (Fig. 27). Paratypes: 14 alatae and 3 apteræ on 12 slides all with same data as holotype. Holotype, morphotype, and paratypes (nine alatae and one apteræ) deposited in the collection of the Museum National D'Histoire Naturelle, Paris. Four paratypes (two alatae and two apteræ) deposited in the collection of the Illinois Natural History Survey, one paratype (alata) sent to each of the following: United States National Museum, Beltsville, the Canadian National Collection, Ottawa and the Natural History Museum, London.

*Discrimination:* The apteræ can be distinguished from all other *Mindarus* species by the WGP formula on the thorax. The number of secondary sensoria on antennal segment III, 45–54, in the alatae is greater than known for any other *Mindarus* species.

*Etymology:* This species is named after Dr. George Remaudière in recognition of his dedication to the study of aphids and his contributions to our knowledge of this most interesting group. He has been of considerable assistance in this study as well as many others.

#### *Mindarus victoria* Essig

Prior to this paper, this species has not been reported since Essig's original description of specimens from Vancouver Island, British Columbia, on *Abies grandis* (Essig 1939). Collections from the Sierra Nevada, Mt. Shasta in northern California and Idaho on *Abies concolor* all contained specimens of *M. victoria*. This is a considerable range extension, however, its use of *Abies concolor* is not surprising given that *A. concolor* and *A. grandis* are considered to be closely related and hybridize easily.

The description given by Essig is accurate

so no new description will be given here but a summary of measurements made during this study is included in Table 1. Essig used the count of secondary sensoria to separate *M. victoria* from other species. This character is unreliable in that it overlaps *M. kinseyi* and *M. obliquus*. *Mindarus victoria* can be separated from other North American *Mindarus* by the following combination of characters. In alatae, the second hind tarsal segment >0.22 mm, sclerotic bands on abdomen very pale not enclosing membranous wax glands and the secondary sensoria on antennal segment III often not parallel sided, rather appearing as irregular polygons especially on the distal half of the segment (Fig. 32). In apteræ the dorsum is free of sclerotization, length of second hind tarsal segment >0.20 mm and wax gland plates are large and lack a distinct outer sclerotized ring (Fig. 33), WGP formula is 2.0.0:4.4.4.4.4.6(5).4 (Fig. 7F). The oviparae are much larger than seen in any other species (compare Figs. 22 and 23) and mounted specimens have been seen with as many as five eggs.

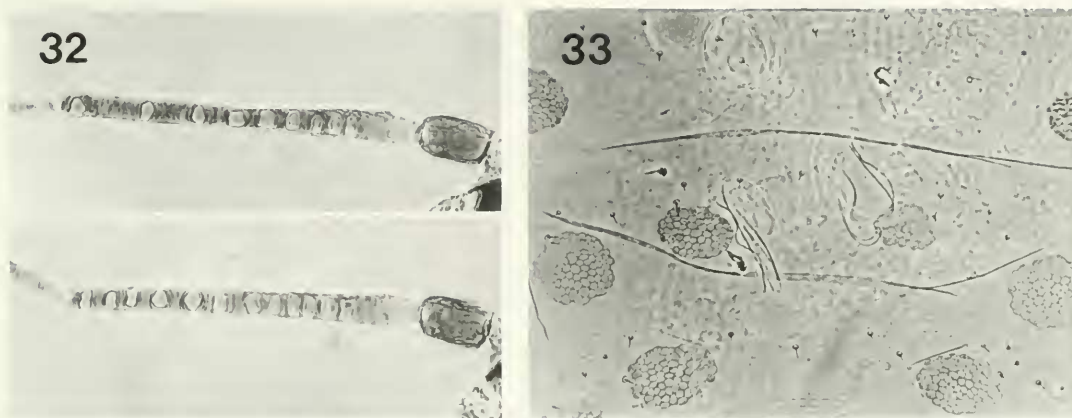
#### *Mindarus obliquus* (Cholodkovsky)

I have examined only a limited number of specimens labeled as *M. obliquus*. The few apteræ seen have a WGP formula similar to *M. kinseyi* so they are easily separated from *M. abietinus*. The alatae are small and often have more than one secondary sensoria on antennal segment IV. In these characters it overlaps with *M. kinseyi*, however, its host specificity (Carter and Eastop 1973) and differences in chromosomes (Robinson and Chen 1969) make it clear that it is distinct from the species feeding on *Abies* spp. At present there is no morphological basis for distinguishing between apteræ or alatae of *M. obliquus* and *M. kinseyi*.

#### DISCUSSION

Heie (1967) noted that the Asian species *M. japonicus* Takahashi overlaps in counts





Figs. 32, 33. 32, Antennal segment III from two alatae of *M. victoria* showing distinct polygonal shape of sensoria, especially on distal half of segment. 33, Abdomen of aptera of *M. victoria* showing wax gland plates without a distinct outer sclerotized ring.

of secondary sensoria with *M. abietinus* and suggested that they are only isolated geographical populations of the same species. I think there is little to be gained from this concept. Detailed studies such as that carried out by Ehler and Kinsey (in press) and additional morphological examination will undoubtedly reveal distinct biological and morphological differences between populations of *Mindarus* which are great enough to warrant specific standing. Additional work on the *Mindarus* spp. in North America needs to be done and is in progress. This study has focused primarily on western North America but I have collected and examined material from the eastern half of the country and the Rocky Mountain region. Much of this material shows distinctive wax gland patterns which need to be verified with collections over several years from a variety of elevations and locations.

Unfortunately the prospects for accurate identification of trap collected alate *Mindarus* are not good. Limits of variation will have to be developed from material which can be associated with identifiable apterae. Eventually it may be possible to develop discriminant functions for alatae. Unfortunately the abbreviated life cycle of most

of the species makes gathering this material a long term project.

#### ACKNOWLEDGMENTS

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